DEPARTMENT OF THE AIR FORCE
59TH MEDICAL WING (AETC)
JOINT BASE SAN ANTONIO - LACKLAND TEXAS

3 JUN 2016

MEMORANDUM FOR SGDTG
ATTN: CAPT DUKE NGUYEN

FROM: 59 MDW/SGVU

SUBJECT: Professional Presentation Approval

1. Your paper, entitled **Depth of Cure of Proximal Composite Restorations using a New Perforated Metal Matrix** presented at/published to **General Dentistry** with MDWI 41-108, and has been assigned local file #**16209.**

2. Pertinent biographic information (name of author(s), title, etc.) has been entered into our computer file. Please advise us (by phone or mail) that your presentation was given. At that time, we will need the date (month, day and year) along with the location of your presentation. It is important to update this information so that we can provide quality support for you, your department, and the Medical Center commander. This information is used to document the scholarly activities of our professional staff and students, which is an essential component of Wilford Hall Ambulatory Surgical Center (WHASC) internship and residency programs.

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Linda Steel-Goodwin

LINDA STEEL-GOODWIN, Col, USAF, BSC
Director, Clinical Investigations & Research Support

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PROCESSING OF PROFESSIONAL MEDICAL RESEARCH/TECHNICAL PUBLICATIONS/PRESENTATIONS

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	Duke Nguyen, CPT, SGDTG	☒ YES ☐ NO	FMH20150019N

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In Vitro Evaluation of a New Perforated Metal Matrix on Class II Composite Resin Restorations Filled in Bulk

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Depth of Cure of Proximal Composite Restorations using a New Perforated Metal Matrix

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Vandewalle, Kraig, S. kraig.vandewalle.3@us.af.mil	210-671-9822

15. AUTHORSHIP AND CO-AUTHOR(S) List in the order they will appear in the manuscript.

LAST NAME, FIRST NAME AND M.I.	GRADE/RANK	SQUADRON/GROUP/OFFICE SYMBOL	INSTITUTION (If not 59 MDW)
a. Primary/Corresponding Author Nguyen, Duke	CPT	59 DTS/59 DG/SGDTG	
b. Motyka, Nancy	Col	59 DTS/59 DG/SGDTG	
c. Meyers, Erik	Civ	96 Medical Group	Eglin AFB, FL
d. Vandewalle, Kraig	Civ	59 DTS/59 DG/SGDTG	
e.			
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16. AUTHOR'S PRINTED NAME, RANK, GRADE	17. AUTHOR'S SIGNATURE	18. DATE
Duke Nguyen, CPT	NGUYEN.DUKE.PHU.1400179022	May 03, 2016
19. APPROVING AUTHORITY'S PRINTED NAME, RANK, TITLE	**20. APPROVING AUTHORITY'S SIGNATURE**	**21. DATE**
Nancy Motyka, Col, Program Director, AEGD	MOTYKA.NANCY.C.1262633256	4 May 2016

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Rocky Calcote, PhD, Clinical Research Administrator	CALCOTE.ROCKY.D.1178245844	

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Depth of Cure of Proximal Composite Restorations using a New Perforated Metal Matrix

ABSTRACT

The purpose of this study was to compare the depth of cure of a class 2 preparation filled in bulk with composite and polymerized with tri-sited light curing using a new "micro-windowed" metal matrix compared to techniques using more traditional matrix systems. A divergent proximal box was prepared in an extracted human third molar. The cusp tips were flattened slightly and the preparation was lightly lubricated. A bi-tine ring (V4 Ring, Triodent) and three matrix types were placed: ClearMetal "micro-windowed" metal matrix (Triodent), Composi-Tight 3D Clear matrix (Garrison), and V3 Metal Tab-Matrix (Triodent) (n=10). SonicFill 2 (Kerr) and Herculite Ultra (Kerr) composites were placed in bulk and polymerized with a curing light from the occlusal (20-secs) and from the buccal and lingual (10-secs). The V3 Metal matrix was removed before curing from the proximal following the manufacturers' recommendations. Two additional groups were created with the V3 Metal matrix that were not removed and only cured from the occlusal, using both SonicFill 2 and Herculite Ultra. The composite specimens were removed from the tooth and stored for 24 hours at 37°C. Knoop hardness was determined at one-mm increments at 0.5, 1, 2, 3, 4 and 5mm from the occlusal surface. Percent bottom/maximum hardness ratios were determined based on maximum hardness measured at 0.5 mm from the occlusal surface for each composite. Data were analyzed with separate two-way ANOVAs and Tukey's post hoc tests examining the effect of depth and matrix type or depth and curing mode per composite type on hardness ratios. For both SonicFill 2 and Herculite Ultra, significant differences were found based on depth, but not on type of matrix band. The use of the new perforated metal matrix band (ClearMetal) resulted in depth of cure that was not significantly different than the use of metal (that was removed) or transparent matrix bands when using tri-sited light curing. An 80% hardness ratio was obtained at over 5mm for SonicFill 2 and over 4mm for Herculite Ultra with tri-sited light curing. Tri-sited light curing resulted in significantly greater depth of cure than occlusal curing only.

Clinical Significance

The new perforated metal matrix band may be used instead of solid metal (which was removed) or transparent matrix bands to provide similar depth of cure of composite resins with the possible benefits of malleability and the ability to leave it in place during tri-sited light curing.

INTRODUCTION

When it comes to posterior composites, the ideal clinical situation includes attaining complete depth of cure and a sealed margin with easy placement. Insufficient depth of cure could result in lowered mechanical properties and thus, early failure of the restoration.[1] Insufficient seal could lead to microleakage which could then lead to caries, post-operative sensitivity, or loss of restoration due to bond failure.[2] The incremental layering technique has been the traditional mode of composite-resin placement.[3] Most manufacturers recommend that conventional composite-resin restorative materials should ideally be placed in no more than 2-mm increments due to the attenuation of the light from the curing unit and to minimize stress from polymerization shrinkage. The use of the tri-sited light curing technique (also known as trans-tooth illumination) with laterally reflective wedges and transparent matrices for proximal curing was proposed years ago to maximize marginal restoration quality, but this technique also relied on incremental layering.[4,5,6,7] However, Belvedere[8] claimed that filling a preparation in bulk and using "trans-enamel polymerization", as he called it, produced less polymerization shrinkage using a conventional composite restorative material. Another study showed that tri-sited light curing could improve the depth of cure of conventional composites placed in bulk without increasing polymerization shrinkage stress and resultant cuspal deflection.[9]

Bulk-fill composite restorative materials were recently developed to overcome the clinical concerns of incremental layering such as the incorporation of voids as well as improving chairside efficiency.[10] Manufacturers market their new bulk-fill composites to be placed in increments up to 4 mm with some as much as 5mm. Greater depth of cure is accomplished by increasing the translucency, including greater amounts of photosensitizers, or by incorporating more efficient photoinitiators.[11] In addition, greater depth of cure may potentially be accomplished with tri-sited light curing.

SonicFill is a single-step, bulk-fill hybrid composite resin restorative system recently introduced by Kerr (Orange, CA). According to the manufacturer, SonicFill incorporates a highly-filled proprietary resin with special modifiers that react to sonic energy. Sonic activation lowers the viscosity of the material to allow for easy adaptation to cavity walls. As sonic energy is applied through the handpiece, the modifier reportedly causes the viscosity to drop (up to 87%), increasing the flowability of the composite, enabling quick placement and precise adaptation to the cavity walls. When the sonic energy is stopped, the composite purportedly returns to a more viscous, non-slumping state that is perfect for carving and contouring. The manufacturer's directions for use in the posterior states, "light cure the recommended time from the occlusal, remove the matrix and cure again from the buccal and lingual" (www.kerrdental.com). The

manufacturer claims that SonicFill can be placed in bulk up to 5mm with low volumetric shrinkage and exhibiting high strength properties. Laboratory studies are somewhat equivocal, with some studies showing a 5mm depth of cure and others less than 5mm with SonicFill.[12,13,14,15] Kerr recently introduced SonicFill 2 which reportedly has an improved formulation for better esthetics and greater ease of use (www.kerrdental.com).

One can infer that bulk-fill restorative materials and tri-sited light curing may provide a viable solution to the clinicians' concerns of technique sensitivity and time utilization. One must ask, "Does it matter what type of matrix band is used? Is there a relationship between type of matrix and depth of cure and marginal seal?" Some studies have answered these questions with the findings that different matrix systems have no influence on the clinical performance or *in vitro* sealing ability of Class II composite restorations.[16,17] However, these studies used the conventional layering technique with traditional posterior composite restorative materials, not the most recent bulk-fill composite restorative materials with bulk-placement, or tri-sited light curing. Triodent (Katikati, New Zealand) has recently developed the ClearMetal matrix. They have placed hundreds of "micro-windows" or perforations in a sectional metal band to reportedly give the clinician a cure-through option for increased proximal light penetration while providing malleability of the metal and natural contours.[18] The perforations reportedly allow light activation from the buccal and lingual eliminating the need to remove the matrix band after light activation from the occlusal and prior to light activation from the buccal and lingual. The perforations are covered with a resin to prevent extrusion of the composite resin (www.triodent.com). Currently, no research has been accomplished evaluating the depth of cure of posterior composite preparations filled in bulk with a composite restorative material using different types of sectional matrix band systems and techniques and tri-sighted light activation. The purpose of this study was to evaluate the depth of cure of a bulk-fill, sonically activated, hybrid composite, SonicFill 2 (shade A2), and a conventional, hybrid composite, Herculite Ultra (shade A2), by Kerr (www.kerrdental.com) using a new perforated ClearMetal matrix band, a more traditional metal matrix band (V3 metal Tab-Matrix, Triodent) that was removed before buccal and lingual light curing, or a transparent (Composi-Tight 3D Clear matrix, Garrison Dental Solutions, Spring Lake, MI) sectional matrix system. See Figure 1. Both composite resin restorative materials were placed in the preparation in one bulk-filled increment. The null hypotheses tested was that class II preparations filled in bulk with composite resin would show no difference in Knoop hardness ratios based on 1) matrix, 2) composite material, 3) depth, or 4) curing mode.

MATERIALS AND METHODS

One extracted human third molar was collected and stored in a 0.5% Chloramine-T solution (Alfa Chemistry, Stony Brook, NY). The cusp tips were ground flat slightly with a model trimmer (12" Model Trimmer, Whip Mix Corp, Louisville, KY) in order to standardize the distance from the light source to the composite resin.

A box was prepared on the mesial of the extracted molar measuring 5.1 mm (occluso-gingivally) X 4.0 mm (bucco-lingually) X 1.5 mm (mesio-distally or axially) using a high-speed handpiece (430 SWL Starbright, StarDental, Lancaster, PA), a NTI, flat-end cylinder diamond (SC835-010, Axis Dental, Coppell, TX), and an enamel hatchet (51/52 Hatchet, Hu-Friedy Mfg. Co., LLC, Chicago, IL). The box had a slight divergent preparation to facilitate removal of the restoration. All measurements were made using an electronic digital caliper (GA182, Grobet Vigor, Carlstadt, NJ). The prepared tooth specimen was mounted next to an unprepared module tooth (ModuPro Endo Module, Acadental, Overland Park, KS) using vinyl polysiloxane impression material (Regisil 2x, Dentsply International, Inc., York, PA) to simulate as closely as possible, a clinical situation during restoration placement. See Figure 2.

The preparation was lightly coated with petroleum jelly (Equate, Walmart, Bentonville, AR) to facilitate removal of the restoration. Light activation of the composites was completed using a mounted light curing unit (Bluephase G2, Ivoclar Vivadent, Amherst, NY) centered over the preparation. The light emission from the Bluephase G2 was analyzed with a laser power meter (FieldMax II, Coherent, Inc., Santa Clara, CA). The curing light was connected to a power cord to provide continuous, consistent operation. The emitted light was measured with the power meter during a 20-second curing cycle three separate cycles and a mean irradiance of 1202 ± 5 mW/cm^2 was determined.

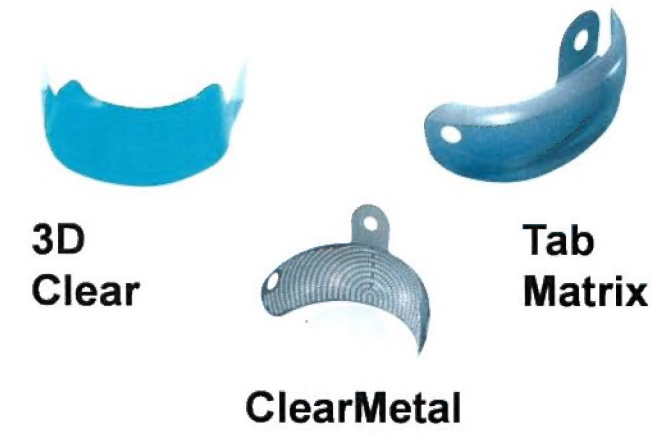

Figure 1: Three matrix types evaluated.

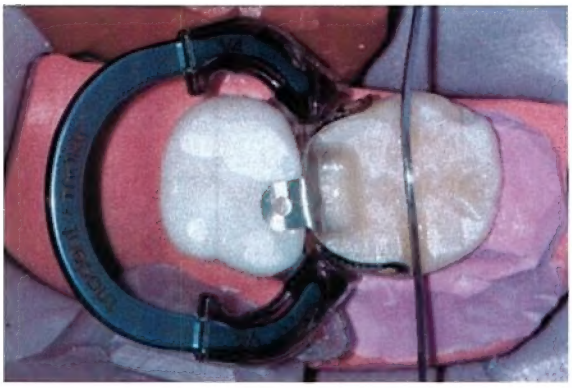

Figure 2: Prepared molar with metal matrix, bi-tine ring and wedge mounted in ModuPro with module tooth.

Eight groups were created based on type of matrix (perforated, metal, transparent), composite type (bulk-fill, conventional), or curing mode (tri-sited, occlusal only). Ten specimens were prepared per group.

Group 1: SonicFill 2 was placed in one bulk increment in the box preparation with the perforated ClearMetal matrix, a light-reflective wedge (V4 Wedge, Triodent), and a metal bi-tine ring (V4 Ring, Triodent) in position around the preparation. Light activation was completed from the occlusal for twenty seconds. Then, the curing light was directed from the buccal and from the lingual for ten seconds each (i.e., tri-sited light curing). The light guide from the curing light was held in a custom polyvinylsiloxane jig to standardize the angle and distance from the tooth. The ring, wedge, and matrix were removed.

Group 2: SonicFill 2 was placed in one bulk increment in the box preparation using a metal matrix (V3 Tab-Matrix), a light-reflective wedge, and a metal bi-tine ring as before. Light activation was completed from the occlusal for twenty seconds. The bi-tine ring was removed. Following the manufacturers' instructions of SonicFill 2 and V3 Tab-Matrix, the matrix band was also removed with the use of a hemostat taking care to keep the light reflective wedge still in place. Tri-sited light curing was completed from the buccal and lingual for ten seconds each as before. The wedge was then removed.

Group 3: SonicFill 2 was placed in one bulk increment in the box preparation with a clear matrix (Composi-Tight 3D Clear matrix), a light-reflective wedge, and a metal bi-tine ring as before. Light activation was completed as before. The ring, wedge, and matrix were then removed.

Group 4: Herculite Ultra was placed and light cured in one bulk increment in the box preparation with a ClearMetal matrix, a light-reflective wedge, and a metal bi-tine ring similar to Group 1.

Group 5: Herculite Ultra was placed and light cured in one bulk increment in the box preparation with a V3 Tab-Matrix, a light-reflective wedge, and a metal bi-tine ring similar to Group 2.

Group 6: Herculite Ultra was placed and light cured in one bulk increment in the box preparation with a Composi-Tight 3D Clear matrix, a light-reflective wedge, and a metal bi-tine ring similar to Group 3.

To compare tri-sited light curing to composite specimens only cured from the occlusal, two additional groups (Groups 7 and 8) were made using light curing only for 20 seconds from the occlusal for each of the two composite resin materials using the metal matrix (V3 Tab-Matrix), a light-reflective wedge, and a metal bi-tine ring.

The specimens were removed from the tooth and any flash and/or excess composite resin was removed using a FG superfine diamond (SF858-014, Axis Dental) and Super Snap Disks-Mini (Shofu Dental Corp, San Marcos, CA). The cameo surface was flattened to be parallel with the intaglio surface using an NTI FG diamond donut (M909-037, Axis Dental). The specimens were stored in a light-proof box with moist paper in a laboratory oven (Model 20 GC, Quincy Lab Corp, Chicago, IL) at 37°C for 24 hours. The intaglio surface was polished with 100-, 220-, 600-, and 1500-grit sandpaper and mounted on a glass slide. The intaglio surface of the specimens were analyzed at one-mm increments at 1, 2, 3, 4 and 5mm from the occlusal surface utilizing a Knoop Hardness tester (Leco, LM300AT, St Joseph, MI) with a 200 gram load for 10 seconds. The hardness at each depth was expressed as a ratio of the hardness at that depth

divided by the maximum hardness. Maximum hardness was recorded to be the maximum hardness determined at the 0.5 mm increment for each of the two composite restorative materials. A mean Knoop hardness ratio and standard deviation was determined at each depth. The composite was considered to be adequately cured at each depth if the hardness ratio was greater than 80%.[19] The tri-sited light-curing data were analyzed with a 3-way ANOVA to evaluate the effect of composite type, matrix band or depth on Knoop hardness ratios. The occlusal-only light-curing data was compared with the tri-sited data with a 3-way ANOVA to evaluate the effect of composite type, depth, or light-curing mode on Knoop hardness ratios of the metal-matrix specimens.

RESULTS

The results of the 3-way ANOVA for tri-sited light curing found a significant difference in hardness ratios based on composite ($p<0.001$) and depth ($p<0.001$), but no difference based on matrix band ($p=0.487$). However there was a significant interaction with composite and depth ($p<0.001$). The data was further analyzed with two-way ANOVAs and Tukey's post hoc tests per composite type. A Bonferroni correction was applied because multiple comparisons were completed (alpha = 0.025). See Table 1 and Figures 3 and 4. For both SonicFill 2 and Herculite Ultra, significant differences were found in hardness ratios based on depth ($p<0.001$), but not on type of matrix band ($p>0.30$) with no significant interactions ($p>0.86$). The use of the new perforated metal matrix band (ClearMetal) resulted in a depth of cure that was not significantly different than the use of metal (that was removed) or transparent matrix bands when using tri-sited light curing. A significant reduction in hardness ratios occurred after 4mm of depth with SonicFill 2 and 3mm with Herculite Ultra. Unpaired t-tests were used to compare the hardness ratio between SonicFill 2 and Herculite Ultra with each matrix band type at each depth. SonicFill 2 had significantly greater hardness ratios at 4 and 5 mm than Herculite Ultra for all three matrix band types ($p<0.025$). The 80% hardness ratio was obtained at over 5mm for SonicFill 2 and over 4mm for Herculite Ultra with tri-sited light curing.

		Percent Knoop Hardness Ratios Tri-sited Curing					
Composite	**Matrix**	**1mm**	**2mm**	**3mm**	**4mm**	**5mm**	Total Mean
SonicFill 2	ClearMetal	93.0 (3.5)	92.0 (2.8)	90.9 (3.2)	89.2 (4.6)	84.0 (5.2)	89.8 (5.1) a
	Metal	91.8 (3.1)	91.6 (3.1)	92.0 (2.9)	90.8 (3.6)	84.8 (4.2)	90.2 (4.4) a
	Clear	92.1 (6.6)	92.5 (5.0)	92.2 (5.2)	89.3 (5.2)	83.7 (4.9)	90.0 (6.4) a
	Total Mean	92.3 (4.8) A	92.0 (3.8) A	91.7 (4.0) A	89.8 (4.7) A	84.2 (5.0) B	
Groups with the same upper case letter per row or lower case letter per column are not significantly different (p>0.05)							
Composite	**Matrix**	**1mm**	**2mm**	**3mm**	**4mm**	**5mm**	Total Mean
Herculite Ultra	ClearMetal	91.3 (1.8)	91.9 (3.7)	89.0 (2.7)	83.4 (4.4)	75.3 (4.5)	86.2 (7.2) a
	Metal	91.1 (5.4)	89.7 (5.6)	87.9 (5.0)	83.1 (6.1)	77.6 (6.7)	85.9 (7.7) a
	Clear	91.5 (2.3)	88.5 (2.6)	86.4 (3.3)	81.2 (4.7)	76.2 (6.0)	84.7 (6.9) a
	Total Mean	91.3 (3.6) A	90.0 (4.5) A	87.7 (4.0) A	82.6 (5.3) B	76.4 (6.0) C	
Groups with the same upper case letter per row or lower case letter per column are not significantly different (p>0.025)							

Table1: Percent Knoop Hardness ratios using tri-sited light curing

The results of the 3-way ANOVA for tri-sited versus occlusal only light curing with the metal matrix band found a significant difference in hardness ratios based on composite ($p<0.001$), depth ($p<0.001$), and light curing mode ($p<0.001$), but there were significant interactions ($p<0.001$). The data was further analyzed with two-way ANOVA and Tukey's post hoc test per composite type. A Bonferroni correction was applied because multiple comparisons were completed (alpha = 0.025). See Table 2 and Figures 3 and 4. For both SonicFill 2 and Herculite Ultra, significant differences were found in hardness ratios based on depth ($p<0.001$), and light curing mode ($p<0.001$) with no significant interactions ($p>0.15$). Tri-sited light curing resulted in significantly greater hardness ratios than occlusal only light curing for both SonicFill 2 and Herculite Ultra. A significant reduction in hardness ratios occurred after 4mm of depth with SonicFill 2 and 3mm with Herculite Ultra. Unpaired t-tests were used to compare the hardness ratio between SonicFill 2 and Herculite Ultra at each depth. Both SonicFill 2 and Herculite Ultra had significantly greater hardness ratios at each depth with tri-sited light curing compared to occlusal curing only ($p<0.025$) with the metal matrix band. With occlusal curing only, the 80% hardness ratio was less than 5mm for SonicFill 2 and less than 3mm for Herculite Ultra.

		Percent Knoop Hardness Ratios Tri-sited vs. Occlusal Only with Metal Matrix					
Composite	**Curing Mode**	**1mm**	**2mm**	**3mm**	**4mm**	**5mm**	Total Mean
SonicFill 2	Tri-sited	91.8 (3.1)	91.6 (3.1)	92.0 (2.9)	90.8 (3.6)	84.8 (4.2)	90.2 (4.4) a
	Occlusal	85.4 (4.2)	87.3 (3.4)	87.7 (3.5)	83.0 (3.8)	78.0 (6.1)	84.3 (5.6) b
	Total Mean	88.5 (5.0) A	89.4 (4.0) A	89.9 (4.0) A	86.9 (5.5) A	81.4 (6.4) B	
Groups with the same upper case letter per row or lower case letter per column are not significantly different (p>0.05)							
Herculite Ultra	Tri-sited	91.1 (5.4)	89.7 (5.6)	87.9 (5.0)	83.1 (6.1)	77.6 (6.7)	85.9 (7.7) a
	Occlusal	83.5 (8.1)	82.7 (8.8)	77.9 (8.6)	70.3 (10.7)	58.4 (11.8)	74.6 (13.6) b
	Total Mean	87.3 (8.1) A	86.2 (8.4) A	82.9 (8.8) AB	76.7 (11.1) B	68.0 (13.9) C	
Groups with the same upper case letter per row or lower case letter per column are not significantly different (p>0.025)							

Table 2: Percent Knoop Hardness ratios comparing tri-sited to occlusal only light curing

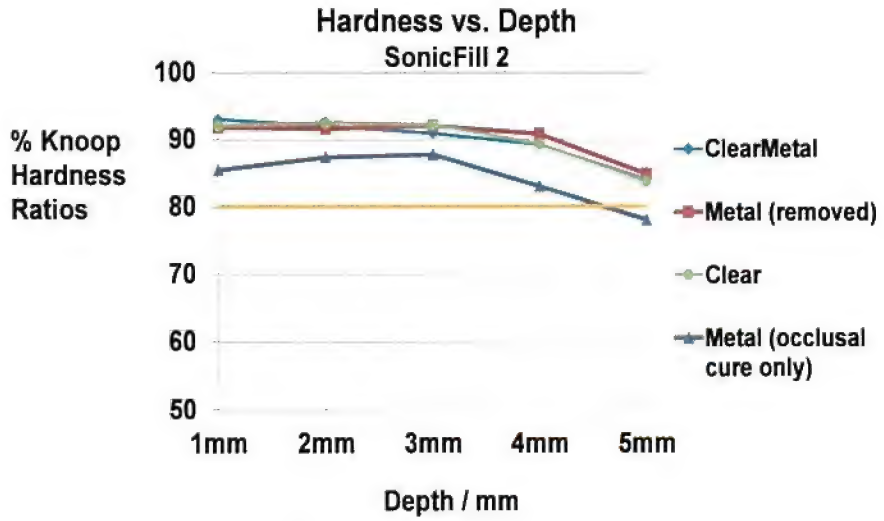

Figure 3: Knoop hardness ratios at various depths using SonicFill 2. The yellow line at 80% represents the threshold for adequate polymerization.

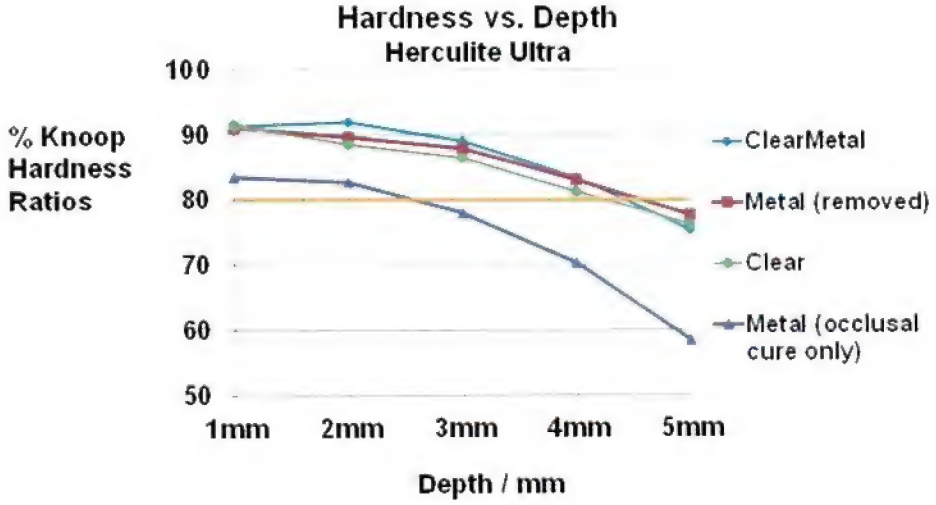

Figure 4: Knoop hardness ratios at various depths using Herculite Ultra. Yellow line at 80% represents the threshold for adequate polymerization.

DISCUSSION

No difference in hardness ratios was found based on type of matrix band technique, so the first null hypothesis was not rejected. The use of the new perforated metal matrix band (ClearMetal) resulted in a depth of cure that was not significantly different than the use of metal (that was removed) or transparent matrix bands when using tri-sited light curing. Previous studies have evaluated the effect of matrix band type on performance *in vivo*[16] and marginal seal and marginal staining *in vitro.*[17] In the Demarco et al.[16] clinical study, the effects of metallic and translucent polyester matrices were compared in class II composite restorations. The method of composite placement and light curing, however, were different compared to this current study. First, incremental insertion (<2mm thickness), not bulk placement, was utilized in both groups. For the metal-matrix group, each increment was cured from the occlusal for 20 seconds. In the translucent matrix group, the first layer was cured through the reflective wedge and translucent matrix for 60 seconds. The second and third layers were cured from the buccal and lingual for 60 seconds each, and any additional layers were cured for 20 seconds from the occlusal. For both groups, after the removal of the matrix bands, additional curing was performed from the buccal, lingual, and occlusal for 20 seconds each. The authors concluded that there was no influence of matrix system on the clinical performance of posterior composite restorations after 4 years. In the study by Hofmann and Hunecke,[17] the effect of light curing protocols and matrix type were evaluated to determine the margin quality and seal of class II composite restorations. Metal matrix and translucent bands were tested. Light curing protocols included high intensity curing, ramp curing, and pulse delay curing. Although tri-sited curing was mentioned in their introduction, light curing was done from the occlusal only. The authors concluded that the curing protocol and matrix type did not influence the margin quality and marginal seal.

Considering these results, one might conclude that the "micro-windowed" ClearMetal matrix system has no potential clinical benefit over conventional matrices. However, one must consider the other characteristics of the band. The malleability of the metal may provide the added benefit of better reproduction of the anatomical/natural proximal form compared to transparent polyester matrix bands. The ability to leave the band in place before light curing from the proximal may provide greater convenience compared to the solid metal matrix bands that must be removed before tri-sited light curing. In addition, research has demonstrated that the use of flat circumferential matrix bands may result in abnormally small or large interproximal areas that may lead to loss of marginal ridge strength or greater food impaction compared to pre-contoured segmental matrix bands.[20,21] Over twenty years ago, Belvedere described a method

of drilling a 4 mm hole in the buccal and lingual of a metal matrix band to direct the curing light energy into the restoration.[22]

The second and third null hypotheses were rejected. Differences in hardness ratios were found based on composite material and depth. Both of these variables, composite material and depth, were interrelated. SonicFill 2 had significantly greater hardness ratios at 4 and 5 mm than Herculite Ultra for all three matrix band systems with tri-sited light curing. A significant reduction in hardness ratios occurred after 4mm of depth with SonicFill 2 and 3mm with Herculite Ultra. The depth of cure of SonicFill 2 met the claim by the manufacturer of 5mm with tri-sited light curing. By contrast, the nanohybrid composite, Herculite Ultra, has a maximum recommended incremental cure of 2mm (www.kerrdental.com). With tri-sited light curing, the depth of cure was over 4mm.

Depth of cure refers to the thickness that a resin composite can be placed in order to assure adequate mechanical properties and biocompatibility. Depth of cure has been measured with several techniques, such as bottom/top or bottom/maximum hardness ratios or degree of conversion, or the ISO Standard 4049 "scrape test".[23,24] Hardness testing is a popular indirect method because of its ease of use and good correlation with degree of conversion.[25] The top and bottom surfaces of the specimen are measured for hardness and the ratio of the two values is calculated. The ratio is compared against a minimum value of adequate cure of the bottom surface. Several studies have defined depth of cure based on hardness ratios of 80% - that is, the bottom surface is at least 80% as hard as the top surface. Others have suggested that the bottom surface should be expressed as a ratio of maximum hardness because top surface hardness can vary depending on the curing light or protocol.[25] Historically, hardness ratios are typically completed using metal or plastic molds with light curing from the top or "occlusal" only. However, with the advent of tri-sited curing, the use of molds has become less relevant clinically. So, this study used a single extracted third molar to permit the trans-tooth or trans-matrix band illumination with light and to reduce the variability of the data. Very little research is available evaluating depth of cure of proximal composite restoration using tri-sited light curing and an extracted tooth model.

Bulk-fill composite resins are a relatively new class of materials. The use of the bulk-fill technique undoubtedly simplifies the restorative procedure over incremental placement. However, so far little clinical evidence exists to support one particular composite application method over another.[26,27] Historically, the main concern about the bulk filling technique was that light attenuation may lead to incomplete polymerization at the apical extent of the increment. A recent laboratory study evaluated three high-viscosity bulk-fill composites and found that all three

materials achieved a depth of cure at 4 mm.[28] Studies by Alrahlah et al.[14] and Goracci et al.[15] showed similar results. Another study showed that the increased depth of cure in some bulk-fill materials is due to their higher translucency. The more translucent bulk-fill materials may not be as esthetic as conventional nanohybrid materials.[29] The study by Ilie and Stark[28] found that the amount of light transmitted through SonicFill was the lowest among the bulk-fill composite resins tested and was rather comparable with regular nano- and microhybrid composite resins. The lower translucency of SonicFill was demonstrated in the longer amount of curing time (40 secs) necessary to provide the greater depth of cure of 5mm.

The fourth null hypothesis was also rejected. Differences in hardness ratios were found based on curing mode when using the metal matrix band. Tri-sited light curing resulted in significantly greater hardness ratios than occlusal only light curing for both SonicFill 2 and Herculite Ultra. With tri-sited light curing, the 80% hardness ratio was obtained at over 5mm for SonicFill 2 and over 4mm for Herculite Ultra. However, with occlusal curing only, the 80% hardness ratio was less than 5mm for SonicFill 2 and less than 3mm for Herculite Ultra. Laboratory studies have shown that enamel and dentin significantly attenuate the light from a curing unit.[30] Very limited research has been published on the effects of tri-sited light curing through tooth structure on depth of cure of composites. A recent study by Hamlin et al.[31] found that while natural human tooth structure significantly attenuates the irradiance from a curing light, "trans-tooth curing of both bulk-fill and conventional composites may aid in the polymerization of resin within deeper areas of the tooth, resulting in greater depth of cure in both composite types." This conclusion was supported in a study by Weaver et al.,[32] which stated that "when a light-activated composite resin is cured through tooth structure, the Knoop hardness number varies inversely with an increase in thickness of tooth structure...and restorations cured through as much as 3 mm of tooth structure may be clinically acceptable." The idea of tri-sited curing was first mentioned by Lutz et al.[4,5,6,7] thirty years ago. In their studies, Lutz et al.[4,5,6,7] showed that tri-sited light curing demonstrated the best and most stress-resistant marginal adaptation. Curing from the buccal and lingual has taken on different names, such as trans-enamel polymerization,[8] trans-tooth irradiation technique,[33] and transtooth-illumination.[9] This author prefers the term tri-sited light curing which includes curing from the occlusal in addition to curing from the buccal and lingual.

A limitation to this study is that only one bulk-fill composite resin, one conventional hybrid composite resin, and one light-curing unit was used. Future studies could examine how the perforated metal matrix band replicates proximal contour and tightness compared to other systems, especially transparent matrix bands. Also, a clinical-user survey of operators could be

conducted to compare the ease-of-use and time efficiency of these new "micro-windowed" metal matrix bands.

CONCLUSIONS

The use of the new perforated metal matrix band resulted in depth of cure that was not significantly different than the use of metal (that was removed) or transparent matrix bands when using tri-sited light curing. The new perforated metal matrix band may be used instead of solid metal or transparent plastic matrix bands to provide similar depth of cure of composite resins with the possible benefits of malleability and the ability to leave it in place during tri-sited light curing. Tri-sited light curing resulted in significantly greater depth of cure than occlusal curing only.

Disclaimer

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